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COGNITIVE TUNNELING, AIRCRAFT-PILOT COUPLING DESIGN ISSUES AND SCENARIO INTERPRETATION UNDER STRESS IN RECENT AIRLINE ACCIDENTS

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By building upon a number of accident reports and on cognitive psychology literature, this paper addresses the effect of stress on the reasoning abilities and on the perceptual processes of pilots. We examine several cases, including American Airlines 587 (New York, 2001), United Airlines 173 (Portland, 1978), KLM 4508 (Tenerife, 1977), Northwest Airlines 6231(Thiells NY, 1974), and Eastern Airlines 401 (Everglades, 1972), in which pilots have, or may have, contributed to an accident by incorrectly interpreting the unfolding scenario, and specifically by disregarding alternative interpretations of the unfolding scenario. While current research efforts have yet to provide guidance on how to successfully handle the problems discussed in this paper, examination of prior accidents may shed some light on the issue.

Introduction

Operator performance under stress is a topic that has been under scrutiny for decades. In an environment in which operational settings contain a range of stressors, it is important to understand the effects of these stressors on operator performance in order to compensate for the possible decrements that result. One specific operational setting which has been prominent in this field is the aircraft cockpit. Aircraft pilots are faced with an array of stressors, ranging from environmental stressors to which they are routinely exposed and trained to endure, to those associated with emergency situations. Although there has been extensive research in the field, creating situations in which equivalent stress is produced has proven quite difficult if not impossible. The levels of stress induced, though probably lower than those with which a pilot would be faced during an emergency, have proven successful in detecting effects on pilot/operator performance. Some conflicting data have resulted; however, enough studies have come to the same conclusion that stress can have negative effects on operator/pilot performance in several different modes (Wickens, et al., 1993), (Driskell, et al., 1999), (Barnett & Wickens, 1986 as cited by Wickens et al., 1993). Research has indicated that the arousal of stress may severely disrupt a pilot's ability to objectively evaluate the situation with which he is faced. Specifically, cognitive tunneling can occur. Cognitive tunneling is a phenomenon in which a pilot will not adequately perceive all pertinent information because of filtering based on preexisting expectations, initial impressions or other undefined factors. This increases the likelihood that sensorial stimuli and alternative scenario interpretations would only be considered if consistent with these pre-existing expectations. While there is limited experimental data on the effects of stress equivalent to that experienced during a flight emergency, aviation safety records provide examples of this phenomenon. There are limitations to studying cognitive tunneling through post hoc analysis of accidents: it is subject to 20/20 hindsight and provides limited basis for generalization and prediction (Wickens et al., 1993). However analysis through experimental research has its disadvantages as well: it is difficult to achieve the level of stress that operators would face in an emergency. That is why it may be useful to explore this phenomenon through both approaches. In the following sections, the effects that stress has been found to have on operator/pilot performance will be examined, and several flights resulting in aircraft accidents will be reconstructed to explore the effect that stress had on the respective flight crews. The goal of this paper is to fill in some of the gaps left open by research with the archival analysis of previous accidents.

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Cognitive Tunneling and its Cohorts

Cognitive tunneling has been recognized for years as a threat to operators who are faced with difficult decisions in the midst of an emergency. It is one of the many theories that surround decision making under stress. It does not act alone, however. Cognitive tunneling, sometimes referred to as attention narrowing, works in conjunction with several other phenomena that may collectively severely affect an operator's decision-making. The effects of these phenomena are cumulative, and as each occurs, the detrimental effect of the previous is often increased. Consequently, the operator is typically left with a decreasing amount of relevant information with which to work, more puzzling phenomena, and an increasing load on her/his cognitive processes. Wickens et al. (1993) present a model which provides an effective illustration of the stages of the decision-making process and the effects that stress has on each. This is the paradigm through which the phenomenon will be examined.

Cue Perception

The first stage, cue perception, is the first phase affected by stress. In most operational environments, there are numerous cues that must be considered when performing the required tasks. When operators are faced with a stressful situation, there is a tendency for the reduction in number of cues that are sampled and therefore perceived (Wickens & Flach, 1988). This selective allocation is referred to as selective attention, and while it is beneficial from a time/resource management point of view, operators sometimes allocate their attention poorly. There are many factors that can influence the distribution of attention, including reliability of the cue, saliency of cue, past experience with the cue, operator's pre-existing expectations and potential outcomes associated (Wickens & Hollands, 2000). Hence, pilots will pay for instance most attention to blinking lights or sounding alarms or to gauges confirming their initial interpretation of a problem. However, there are contradictory stances on the impact that stress has on selective attention. It has been theorized that stress actually improves selective attention. Chajut & Algom (2003), along with several others, have found that by imposing stress on an operator, she/he is better able to focus on the target task and rule out irrelevant cues. This is not entirely contradictory to the theory being presented herein. Stress decreases attention resources, and, therefore, greater efficiency is achieved by not sampling irrelevant cues and focusing on those deemed relevant to the problem. However, some of the cues deemed irrelevant are sometimes relevant, and the "efficiency" achieved comes at the price of embracing an incorrect interpretation of the unfolding scenario.

Working Memory

In the next phase of the model, the hypotheses stored in long-term memory are accessed and those assumed to be relevant are placed in working memory for evaluation. Additional narrowing can occur at this phase. While several hypotheses are stored in long term memory, only those associated with the preexisting expectations and the presumed problem will be retrieved, omitting several possible alternatives. Operators will then likely fixate on these hypotheses. Also, a function of working memory is the evaluation of action outcomes which are also retrieved from long-term memory. Increased stress places greater demands on this already "fragile" working memory, which degrades decision making (Wickens, et al., 1993). Hence, when pilots are faced with emergency situations, instead of evaluating all hypotheses learned in training and through experience, and thoroughly evaluating each, pilots evaluate the hypothesis they believe to be relevant with limited consideration of action outcomes.

The Cohorts

There are many issues that work hand in hand with cognitive tunneling to add to the effects of stress. One of these partners is confirmation bias, which occurs when an operator forms a premature hypothesis and seeks out cues and information to support solely this hypothesis (Wickens & Hollands, 2000). Many times operators believe they know what is causing the problem before they have even considered all the options, and instead of collecting information to test all of the hypotheses, they collect only information pertaining to the presumed cause. The operator is then left with a small set of information with which to work. When this information does not add up and confirmation of the hypothesis is not possible, further potential confirming cues are usually sought, while disconfirming information is usually not considered - the operator tends to perseverate. Belief perseverance, another collaborator, takes place when a person continues with a familiar plan of action even though it is fruitless (Ross & Lepper, 1980).

Expert vs. Novice

There has been extensive research in the area of cognitive tunneling regarding expert/novice differences. Deitch (2002) found that one of the most obvious differences in this area was cognitive mapping, where experts had more sophisticated cognitive maps and could relate their maps to more specific scenarios than novices. Other studies have found that there is a difference between experts and novices for instrument fixation, a task thought to be linked closely to cognitive processes (Harris, Tole, Stephens, & Ephrath, 1982). Additionally, in some tasks, experts even utilized different brain regions than novices (Peres et al., 2000). However, Guilkey (1997) determined that when pilots are faced with especially cognitively exhausting problems, flight time (experts vs. novices) is not a good predictor of performance. Results from this study indicated that no matter the strategy used, experts' performance was equal to novice performance. From these differing results, one can see that there are still many areas in cognition with respect to expert/novice differences to be researched; however, the evidence points to the problem of cognitive tunneling as one which faces both novice and expert pilots alike.

In the following section, the above theories are expounded upon through exploration of their presence in several aircraft accidents. By illustrating the existence of these phenomena in reality, not just in a simulator setting, compelling support is provided for these theories.

Aircraft Accidents

In this section, we examine five accidents in which the phenomenon of cognitive tunneling most likely played a significant role.

- American Airlines 587, Belle Harbor, NY, November 12th 2001 – As the flight was cleared for takeoff, the first officer - the flying pilot - asked the captain whether he thought sufficient distance had been allowed from the preceding plane, a large Japan Airlines aircraft, in order to avoid wake turbulence. The captain stated "aah…yeah...we'll be alright once we get rolling; he's supposed to be five miles by the time we're airborne, that's the idea". Shortly after takeoff the plane encountered wake turbulence, to which the first officer responded with strong aileron inputs. Immediately after the encounter the captain stated: "Little wake turbulence, huh?", to which the first officer replied "Yeah". After a few more seconds, a second wave of wake turbulence was encountered, to which the first officer reacted with strong rudder and aileron inputs. His aggressive action on the flight controls caused the plane to experience significant lateral oscillation, which the first officer erroneously attributed to wake turbulence. As a result, he continued his action on the flight controls, causing the plane to experience increasing side loads and resulting in the loss of the tail and the engines.. Throughout the accident flight, the first officer seemed to be convinced that wake turbulence would be encountered, and that some type of action may be needed. Records indicated that the first officer's preoccupation with wake turbulence was not limited to the accident flight, as he had showed strong reactions to wake turbulence in earlier occasions.

- United Airlines 173, Portland, OR, December 28th 1978 – As the aircraft approached the arrival airport, a problem arose with the landing gear extension. As the gear was lowered, the crew heard a loud "thump, thump," and the airplane yawed to the right. The only gear lights that came on were those indicating the nose gear was down and locked. The flight crew elected to assess the problem while in a holding pattern. However, the fuel level was not adequately monitored, and fuel starvation occurred, which caused the plane to crash before reaching the airport. About one hour elapsed between the time the problem with the gear emerged and the time of the crash. The flight engineer was monitoring the state of the fuel throughout the last segment of the flight and voiced concern to the captain. The flight engineer even stated the amount of fuel, which, considering the fuel burn rate, gives a clear estimate on the amount of time until the fuel would be depleted. However, the captain continued on a path that would keep them in the air longer than the fuel supply allowed. The NTSB determined that the probable cause of the accident was the failure of the captain to properly monitor the aircraft's fuel state and to properly respond to the low fuel state and the crewmember's advisories regarding fuel state (1979). This resulted in fuel exhaustion to all engines. The inattention resulted from preoccupation with a landing gear malfunction and preparations for a possible landing emergency (NTSB, 1979). The only cues being considered were those associated with the landing gear, despite the dire fuel situation. The captain was unable to successfully process the information regarding the fuel state because his attention resources were exhausted dealing with the landing gear problem.

- KLM 4508, Tenerife, March 27th 1977 – Numerous flights were diverted to Tenerife after the Las Palmas Airport closed because of a terrorist attack. The sudden increase in traffic caused congestion at Tenerife so that a KLM Boeing 747 was forced to wait two hours, while another plane, which blocked the taxiway, boarded passengers and refueled. The KLM flight was eventually allowed to move, but takeoff was initiated before a clearance had been issued. The plane struck another Boeing 747 that was taxing on the runway, resulting in the worst accident ever in the airline industry. During the takeoff roll, the KLM flight crew warned the captain that they might not have been cleared for takeoff and that another plane might have been taxing on the runway. However, the captain seemed to be strongly convinced that they had been cleared for takeoff and discarded the flight crew's comments.

- Northwest Airlines 6231, Thiells, NY, December 1st, 1974 – As the aircraft was climbing in icing conditions, the pitot tube became clogged by ice, so that the airspeed indicator started working as an altimeter, indicating increasing airspeed as the plane climbed. The flight crew failed to recognize the problem and instead believed, despite the constant power setting and the climb attitude, that the airspeed was in fact increasing. They believed that this increase was due to the low weight of the aircraft. Their erroneous interpretation lasted throughout the flight, until the plane buffeted, stalled, and entered a rapid descent. The flight crew apparently believed that the buffeting was a high speed phenomenon – Mach buffeting – rather than a stall buffeting and neglected the possibility of a stall despite the indication from the shaker stick. The flight crew relied exclusively on the air speed indicators and their related warning systems, ignoring other pertinent cues pointing to a different problem than the one originally assessed.

- Eastern Airlines 401, Everglades, FL, December 29th, 1972 – As Eastern 401 approached Miami International Airport and lowered the landing gear, the light that indicated that the nose landing gear has lowered and locked failed to illuminate. The crew chose to depart the airport airspace to the west to assess the problem. The auto- pilot was engaged, and they proceeded to evaluate the indicator light and the gear status. As the flight continued, the autopilot became disengaged and a slight descent initiated. Prolonged focus on the landing gear problem prevented the flight crew from monitoring altitude and the plane proceeded to descend, eventually impacting the ground. The NTSB found that the three flight crewmembers were preoccupied in an attempt to ascertain the position of the nose landing gear and therefore neglected monitoring the flight instruments (1973). Much like the crew involved in the accident in Portland in 1978, this crew was focused on the problem with the landing gear and did not sample other cues relating to the state of the aircraft. The flight crew did not even hear the altitude alert which sounded as the aircraft descended through 1, 750 feet m.s.1., an indication that their resources were entirely devoted to the landing gear.

Conclusions and Research Indications

As illustrated in the accidents presented above, cognitive tunneling likely played a role in several aircraft crashes. In all of the accidents discussed above, the pilot did not adequately perceive or evaluate all pertinent information necessary to successfully complete the flight because of filtering based on preexisting expectations, initial interpretations, or preoccupation with one aspect of the flight. The dilemma is evident; however, the solution is not so lucid. Prince et al. (1997) suggest three remedies that can be applied to overcoming the effects of stress in the cockpit: 1) redesign of task/environment, 2) selection of crew based on ability to withstand stressors, and 3) training, the most reasonable intervention. Prince et al.. suggest specific training techniques that appear promising including: integrating specific behavioral techniques designed to assist in dealing with stress, and providing crews the opportunity to practice newly acquired skills under condition of graded exposure to stressors (1997). Glyn (1997) suggested developing a comprehensive aircrew decision making seminar to include awareness training and incorporate pertinent research. In stead of presenting a specific formula for optimal decision making, a range of different decision types is presented along with the different processes used in making a good decision (Glyn, 1997). There are currently pilot training programs that do incorporate stress management and decision making training into their Crew Resource Management (CRM) training (Prince et al., 1997). However, alterations to these programs to include awareness training of the phenomena that can occur as a result of stress, such as cognitive tunneling, may prove beneficial. By exposing pilots to the theories and the research into the effects of stress on performance, and by illustrating these effects through previous accidents and occurrence in actual simulator training, pilots' susceptibility to it may decrease. Further research on pilot training with respect to stress and its effects is needed to better understand how to cope with this issue.

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